Novel Coronavirus Identification from Chest X-Ray Images By Using Convolutional Neural Network

Dr Suneetha K R[1], Dhruv Varshney[2]

[1]*Associate Professor, Department of Computer Science, Bangalore Institute of Technology, Bangalore, India*
[2]*Pre-Final UG Student, Department of Computer Science, Bangalore Institute of Technology, Bangalore, India*

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Abstract --*A Convolutional Neural Network is basically adding a Convolutional layer to the Artificial Neural Network(ANN). In Artificial Neural Network we give various numbers as the input and ANN forms the pattern in between these numbers and give required output .During this current scenario, Although the number of COVID-19 cases are decreasing in various but still the people are losing life ,and the discovery of different variant of COVID-19 make the situation worse. In most of the countries especially in developing countries there are limited detection kit. At this point of time, every individual should behave very responsible and maintain their safety by themselves. This proposed method is implemented in five phases i.e, Data Exploration, Loading the image data, Splitting the data set, Data Augmentation, Performance Evaluation. Here we use normal chest X-rays images of pneumonia (as COVID Negative) and affected chest X-rays images of Covid-19(as COVID Positive) is used to detect deviation in our image dataset. In this paper, we came up with one of the type of Convolutional Neural Network and that is VGG-16. The rating of our model on a testing a dataset shows that the model achieve an average sensitivity rate of approximately 98.0% and an average specificity rate of approximately 98.0%. makes a promising outcome in Covid-19 detection using Chestradiographyimages.*

Key Words: **Covid-19, Deep learning, Chest X-rays, Diagnosis, Classification, Convolutional Neural Network**

1. INTRODUCTION

COVID-19 is a deadly disease which is originated in 2019. It is transmitted from animals to humans via contaminated water before travelling unnoticed to Wuhan, China where it was first detected . In turn, the person is getting infected when the normal person inhales the droplets of the infected person. If the person is feeling symptoms like pyrexia, Nonproductive Cough, tiredness, conjuctivities, loss of taste and smell, chest pain or pressure [2]. Additionally, in order to start diagnosis or detection of any disease, we need to collect the samples of upper and lower airways of the diseased person.

In addition, chest X-rays and CT scans are used in the diagnostic phase.Primarily, there is no exact treatment for the disorder, and this calls for the need to prevent the disease from spreading. Although various vaccines are there in various countries but that vaccines does not ensure that you will not get infected by the novel Coronavirus. Notable prevention strategies are isolation of the infected persons, proper ventilation, hand hygiene and use of personal protective equipment.

Coronavirus is a death-dealing virus of which symptoms can vary from common fever, dry cough, exhaustion to fatal diseases such as Middle East Respiratory Syndrome (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS-CoV). As of 20th June 2021, the total aggregate of worldwide cases of Coronavirus is 179,119,250. Of these, 3,879,010 (2%) people were deaths and 163,658,685 (91%) were recovered. The number of active patients is 11,581,555. [1]

Nowadays the world is struggling with the COVID-19 pandemic. This paper covers the diagnosis of COVID-19 infections using chest scan to verify lung condition, in this way, if the patient shows any disease in the scan, they are presumed to have COVID-19 infection . This method allows the affected patients to be identified and treated in a more rapid and effective manner.

Convolutional neural networks have achieved unique developments in image processing, mainly in the field of additional medical diagnostics technology [3].Convolutional Neural networks has proven itself to be successful in identifying COVID-19 from Chest radiography images, attaining higher accuracy than those of diagnostics methods . In this proposed work the potential of several state-of-the-art, pre-trained convolutional neural networks with respect to involuntary detection of COVID-19 disease from chest X-ray images was evaluated. Various radiography images are taken from the COVID-19 positive patients and normal patients. Since we have limited data associated with COVID-19, so we use Convolutional Neural

Network which is the best deep learning algorithm for image processing.[4]

The use of X-Ray images has proven to be quite effective over conventional diagnostic tests:

1. Imaging of X-Ray is much more constructive than the ordinary diagnostic tests.
2. Transferring digital X-ray images does not require any transfer from the place of capture to the place of inspection, thus greatly speeding up the diagnostic process.
3. Unlike expensive CT scans, mobile X-ray machines also authorize testing in an isolated ward, therefore reducing the need for additional personal protective equipment (PPE), which is an extremely scarce and valuable resource in this framework.
4. It also minimize the possibility of person of getting infected from hospital-acquired diseases[6]. So many test kits are available nowadays , but are either expensive or take time to detect the virus. In this work, we will learn to detect COVID-19 with help of Chest X-Rays by using CNN architecture.

The rest of the proposed work is organized as follows. Section II give out a System design review:

i) The utilization of deep learning for the identification of COVID-19
ii) Classification of COVID-19 patients from the chest X- Ray images, Patients image Datasets and normal images of Covid-19.

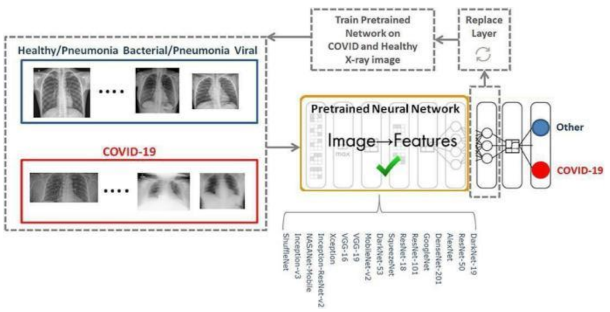

Fig I.a Classifying Various COVID-19 Chest X-Ray Images

Section III expresses the proposed methods and its implementation of the phases. Section IV confer the model building and its architecture, then Section V hand over the experimental results and, Section VI introduce related works. Finally, Section VII concludes the calibre of proposed work and provides direction for further experimentation and analysis.

2 SYSTEM DESIGN

Various research studies employed deep learning techniques on chest X-Ray images with a main objective to identify COVID-19 positive patients and the outcomes that our model achieve is quite impressive in terms of accuracy. With the help of Convolutional Neural Network we can able to determine the coronavirus disease from chest X- ray (CXR) images. The proposed CNN is based on pre- trained deep learning model (VGG16). We use VGG16 in order to achieve high projection accuracy from a small dataset. The images are classified into two categories, Covid and Non-Covid. Further, to avoid the limitations which can be caused due to data inadequacy and training time, a deep learning algorithm is applied by making use of the X-ray image dataset.

The results depicts that the VGG16 model is more reliable on the basis of accuracy in both training and testing stage [4]. In deep learning, this method requires initial training of a CNN for a given task using a large dataset.

The availability of a large dataset is the main factor in ensuring the success of the method as the CNN can learn to extract the most notable features of a sample.The CNN is also appropriate for transfer learning and it is successful in extracting the most important image features [2]. To build the model, a deep learning network, VGG- 16 (Visual Geometry Group) model [5] is used.

In this section, the method of classifying X-ray as a healthy patient or COVID-19 affected patient has been presented. Description of datasets of images is provided in this work and then an explanation of the process of feature removal is mentioned based on deep learning theory.

1.2 Dataset Illustration

The Dataset is divided into two sub dataset that are COVID-19 Negative and COVID-19 positive, COVID-19 positive dataset has been obtained from Dr. Joseph Paul Cohen post-doctoral Fellow, Mila, University of Montreal[13].

Whereas, the Normal images are obtained from the online resource Kaggle. It has two types of X-ray images normal and Pneumonia but only normal X-rays have been used from the dataset so that model learns to identify Covid-19 cases in (Fig I.b) and (Fig I.c). It also contains metadata.csv which contains information about each patient. COVID-19 images are all extracted from this dataset [10]. (Fig I.d) contains some metadata about each patient.

In next section we will talk about the characteristic of transmitting image to the train set, validation set, and test set

Fig I.b. Covid-19 affected chest X-ray

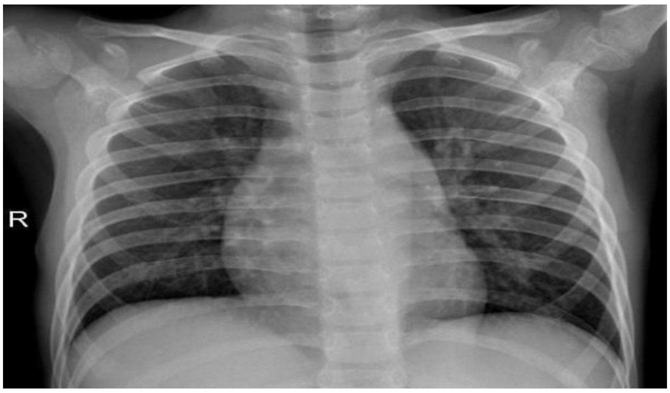

Fig I.c. Normal Pneumonia chest X-ray

	Patientid	offset	sex	age	finding	survival	view	modality	date	location	filename
0	2	0.0	M	65.0	COVID-19	Y	PA	X-ray	2020	NaN	auntminnie-a-2020_01_28_23_51_6665_2020_01_28_...
1	2	3.0	M	65.0	COVID-19	Y	PA	X-ray	2020	NaN	auntminnie-b-2020_01_28_23_51_6665_2020_01_28_...
2	2	5.0	M	65.0	COVID-19	Y	PA	X-ray	2020	NaN	auntminnie-c-2020_01_28_23_51_6665_2020_01_28_...
3	2	6.0	M	65.0	COVID-19	Y	PA	X-ray	2020	NaN	auntminnie-d-2020_01_28_23_51_6665_2020_01_28_...
4	4	0.0	F	52.0	COVID-19	NaN	PA	X-ray	2020	Changhua Christian Hospital, Changhua City, Ta...	nejmc2001573_f1a.jpeg

Fig I.d. Metadatasets of Covid-19 Patients

1.2 Importing the required libraries

The main library we will be using is Tensorflow created by Google in order to detect the COVID-19. The list of necessary libraries needed is shown in **(Fig II.a).**

```
import tensorflow as tf
import pandas as pd
import random
from imutils import paths
from tensorflow.keras.applications import VGG16, VGG19
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.model_selection import train_test_split
from sklearn.metrics import classification_report, confusion_matrix
from sklearn.preprocessing import LabelBinarizer
import cv2
import os
```

Fig II.a Importing the necessary libraries

3. THE PROPOSED METHOD AND ITS IMPLEMENTATION OF THE PHASES

There are several steps to explore the proposed intensive learning-based COVID-19, as illustrated **(Fig II.b).** The phases are summarised in the following five steps:

Step I: Collect the Chest X-Ray images for the dataset from COVID-19 patients (having different probability of Covid-19) and healthy persons.

Step II: By using data augmentation generate chest X- Ray images. [since we are dealing with the dataset having less X-Ray images we use Data augmentation which will create copies of the image]

Step III: Represent the images in a feature space and apply deep learning.

Step IV: Split the used dataset into two sets 1) a training set and 2) validationset.

Step V: Analyse the performance of the detector on the training and validation dataset.

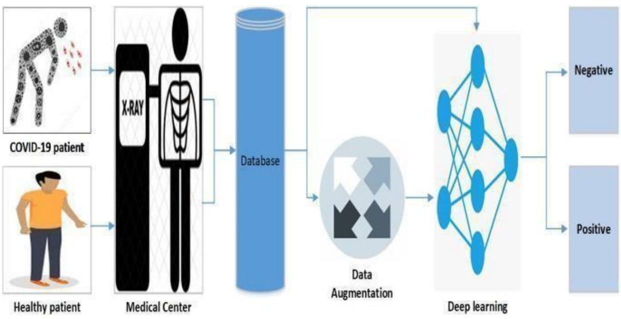

Fig II.b. Summary of Covid-19 Detection Phases

i) Data Exploration

Above, in the (Fig I.d) has the information about the meta Dataset which summarize the main features of a data set, including size, accuracy, initial patterns in the data, and other attributes. i.e, loading the data about data.

ii) Loading the image data

In this work extract all the image paths and use the imread method of the openCV library to read the images. Then convert the images into RGB channel and resize the images to 512 X 512 pixels. Normalize the data by converting the pixel intensities in the range of [0,1] **(Fig II.c).**

iii) Splitting the Dataset

Now, in this section divide the dataset into training, testing and validation sets **(Fig III.a).** To fit the models we consider the training set, while to estimate prediction error for model selection ,the validation set is used and then the test set is used for assessment of the generalization error of the final chosen model. Ideally, the test set should be brought out only at the end of the data analysis.

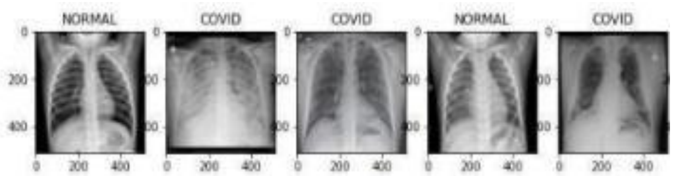

Fig II.c. Chest X-ray images after loading the image data

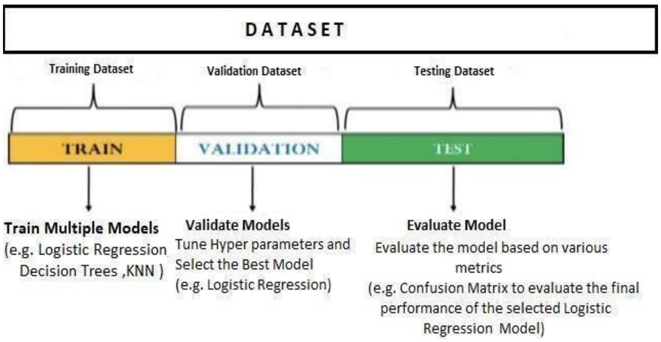

Fig III.a. Splitting of Data Set

iv) Data Augmentation

Data augmentation is a approach that is useful in increasing the diversity of data available to a training model without actually collecting new data. In order to train a large neural network (in our case Convolutional neural network), various data augmentation techniques such as padding, cropping, and horizontal flipping are used. In this work, data augmentation was performed with a number of pre- processing techniques, taking advantage of the Keras image data generator during training, due to insufficient availability of samples. Since data augmentation can enlarge the training data so data augmentation is very effective in reducing the probability of model overfitting.

4 MODEL BUILDING

Here, start building the CNN architecture, and uses the VGG16 network (Visual Geometry Group). The optimizer used is Adagrad with binary cross entropy as the loss function and accuracy as the metrics.

A Convolutional Neural Network (ConvNet/CNN) is a Deep Learning algorithm which is widely used for image processing, which can take in an input image, assign value (learnable weights and biases) to various aspects/objects in the image and then detach one from the another. CNNs can also be used for deep learning applications in healthcare, such as medical imaging as shown in (Fig III.b).

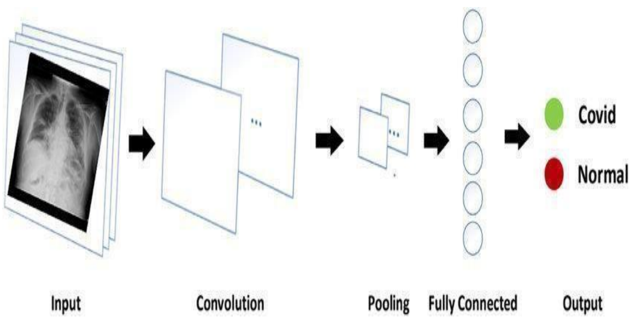

Fig III.b. Basic CNN architecture for classification and detection of COVID-19

A Convolutional Neural Network(CNN) is composed of various levels

1. **Convolution layer** — It is the first layer of Convolutional Neural Network. This layer is responsible to extract important features from an input images. Convolution then conserve the patterns between pixels by learning image features using small sections of the input data.
2. **Pooling layer** (down sampling) —They are used to reduce the various parameters and various computation by reducing the representation's size. They operates on each feature map independently.

3. **Fully connected input layer**—This layer classify the images into a label by using the outcomes which is taken from the convolution/pooling process.
4. **Fully connected layer**— It determines the correct label by using inputs from the feature analysis.
5. **Fully connected output layer**—provides the final probability of all the above layers used

4.1 VGG16 | CNN model | Architecture

This model achieve more than 90% accuracy on ImageNet dataset **(Fig III.c)**, shows the exploited architecture of

proposed model i.e. convolutional neural network model. In order to generalize the proposed model, considered data augmentation by setting the rotation to 15 degrees either clockwise or counter clockwise of any arbitrary Image. The first layer is having Dimensions of 512 X 512 RGB image, for this reason we have to resize the chest- radiography images.

The convolution is adjusted to 1 pixel and then the chest X-ray make to pass through various convolutional layers . Spatial pooling can be accomplished by exploiting 4 maximum-pooling layers, which follow some complex layers .In order to perform Max-pooling we have to consider a 2*2 pixel window. All assumed hidden layers consider a non-linearity. The extension of the VGG-16 architecture includes the following layers as shown by the network (shown in FigIII.c).

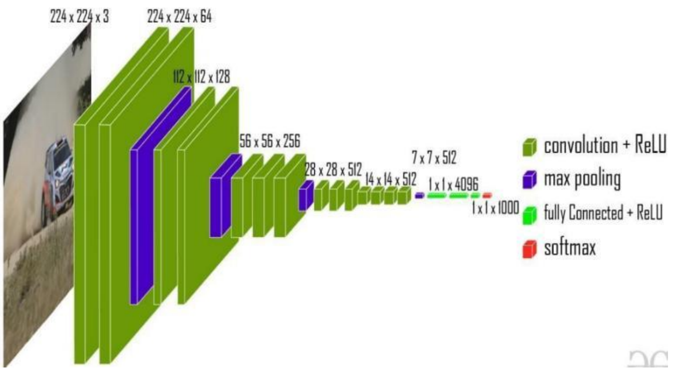

Fig III.c. The VGG16 | CNN model Architecture

1. **Average Pooling2D**—This layer performs the average pooling operation. This layer helps to calculate the mean of each patch of the feature map under analysis. This means that each 2x2 class of the feature map is sampled for the mean value.
2. **Flatten**—It is a utility layer that helps to flatten an input.. Because of flattening, a vector is created from the 2D matrix that can be given into a classifier of fully connected neural network.
3. **Dense**— This layer is mostly used to transform the data .That's why this layer is most widely and frequently used layer. Dense layer reduces the vector of height 512 to a vector of 64 elements. It is the deeply connected neural network layer which means that all the neurons of the previous layer provides some output which in turn becomes the input of the neurons present in dense layer.
4. **Dropout**—This layer basically functions as follows i.e., by selecting neurons on a random basis which should not be considered in the training. The purpose of this layer is to actually modify the normalization, we are strengthening the network to train the same high level concept by exploiting individual neurons. Obviously, we know that exploiting this neurons usually results in poor performance, but our main objective is to create a model that is less sensitive to data changes.
5. **Dense**—Its main purpose is to reduce a vector of height 64 to a vector of 2 elements (ie, two classes to predict) and also reduce numerous effective convolutional layers are shown in **(FigIV.a)**.

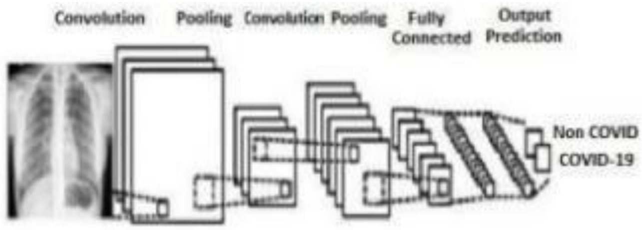

Fig IV.a. Constitutes the simplified representation of CNN architecture for classification of Radiography image

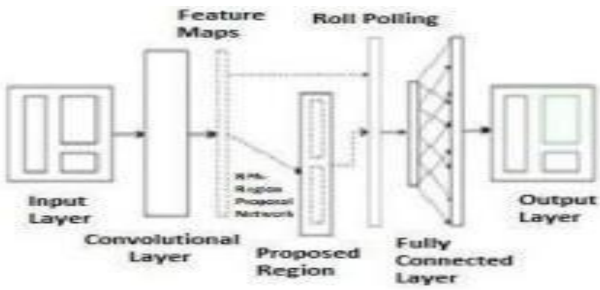

Fig IV.b. Illustrate the pipeline structure of Rapid Regional based Convolutional Neural Network

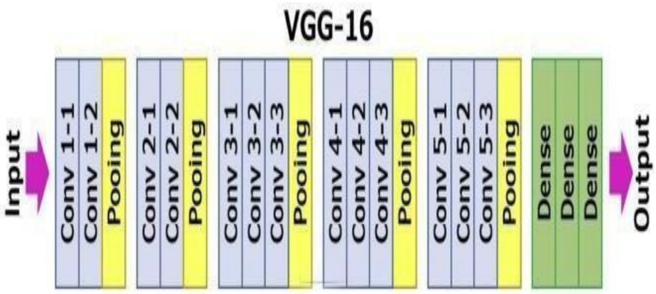

Fig IV.c. The convention of VGG16 network architecture which features the basic structure of convolution, pooling, and dense layers.

5.EXPERIMENTAL RESULTS

i) Experimental Setup

The python programming language was used including the Keras package and a TensorFlow backend in order to train the proposed deep learning models. Keras manages a global state, which it used to specify autogenerated layer names and to implement the functional model- building API . Both TensorFlow and Keras can be installed using pip command.

Initial configuration required for execution of CNNs is :

- Ubuntu 14.04 or later
- Windows 8 or later (with C++redistributable)

ii) Consummation Measures

The consummation measures adopted are,

1. **Accuracy** — It is used for evaluating classification models. Informally, accuracy is the fraction of what our model predicts to be correct. It is the number of correctly predicted data points out of all the data points. In binary classification it is formulated as the number of true positives and true negatives divided by the number of true positives, true negatives, false positives and false negatives [1]

Accuracy (AC) = (tn+tp)/(tn+tp+fn+fp) ——— (1)

2. **Precision** -- The number of correct positive predictions

Calculation: True positives / Amount of positives predicted [2].Amount of positive predictions = sum of true positives and false positive

Precision = tp/ (tp + fp) ——— (2)

3. **Sensitivity** — The percentage of positive cases. Calculation: True positives / Number of actual

positive Sensitivity = tp / (tp + fn) ———— **(3)**

4. **F1 score** —Balance between the senstivity and the precision is conveyed by F1 Score . It is also known as F measure[4].

Specificity = tn / (tn + fp) ———— **(4)**

where tp and tn represent the true-positive and true- negative values respectively whereas fp and fn represent false-positive and false-negative values respectively.

Macro Averaged F1 score is the harmonic mean between precesion and recall. It is used to assess the problems quality with multiple binary labels/ multiple classes.

5.1 Results

In this proposed work the benefits of multiple states of pre-trained convolutional neural networks for COVID-19 disease from chest radiography images were evaluated. Generally a pool of existing deep learning classifiers, namely VGG16.

In this section we have shown the performance of the convolutional neural network.. To finalize the final outcomes the following metrics were considered for each category (covid, non-covid): precision, sensitivity, F1-score, specificity and the overall accuracy of the model is as shown in Table I.

	COVID	NON-COVID
Precision	0.89	0.88
Senstivity	0.96	1.00
F1 Score	0.96	0.98
Specificity	0.90	0.90
Overall Accuracy	**0.9310**	

Table I: Tabulating the performance obtained from VGG16 CNN model

The final outcome prove that VGG16 achieve the best classification accuracy of 93%. Furthermore, the confusion matrices of the best model VGG16 are shown in the **(Fig V.a).** A sensitivity of 96% for the covid class can be observed for VGG16 CNN model .This is vital as the model needs to be able to trace all positive COVID-19 cases to reduce the spread of this pandemic virus in the community. A Graphical representation of overall result is depicted in the Chart -1 & Chart -2.

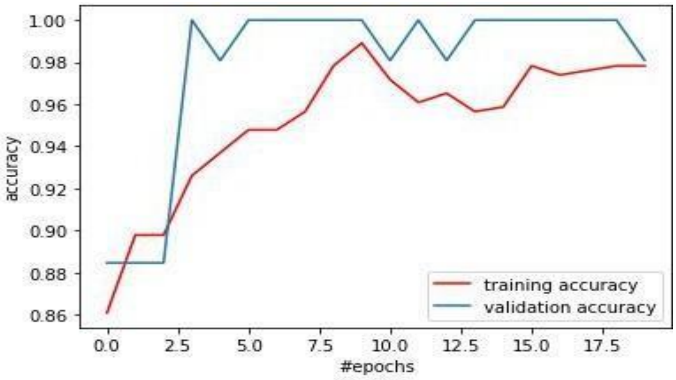

Chart -1: VGG16 accuracy w.r.t epochs on COVID-19 Dataset

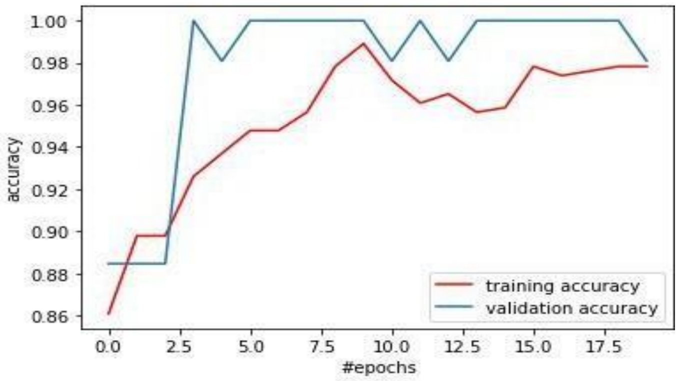

Chart -2: VGG16 loss w.r.t epochs on COVID-19 Dataset

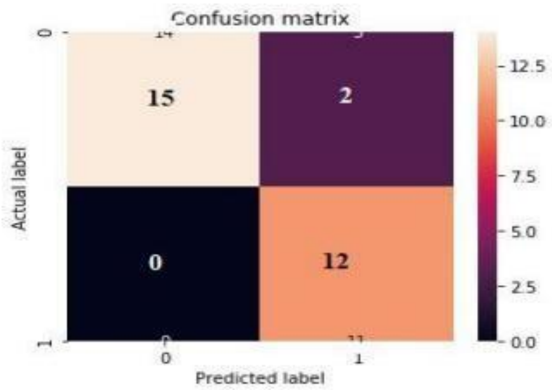

Fig V.a Confusion matrix based on 10-fold cross-validation method

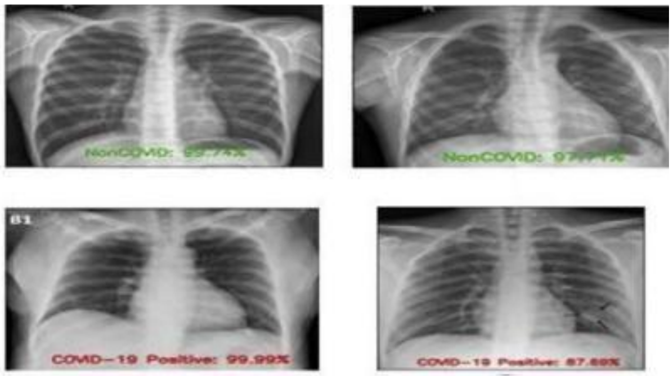

Fig V.a. The various sample X-ray images shown above demonstrate that the model identifies the images as whether covid or non-covid.

6. RELATED WORK

Using of Chest radiography images in order to study the diagnosis has binary or multiple classifications.. Some studies work with raw data while other studies adopts the process of feature extraction. There is a huge variation in the data used by different studies, and it is discovered that convolutional neural network (CNN) is the most preferred method.

AliNarin, Ceren Kaya [1], considered three-diverse binary classifications with 4-different classes that are COVID-19, normal, viral pneumonia and bacterial pneumonia in order to design a method which will automatically detect COVID-19 disease from chest X- Ray images by using Convolutional Neural Network(CNN)

Elene Firmeza Ohata, Gabriel Maia Bezerra [2], developed Automatic detection of COVID-19 infection from chest x-ray images by using transfer learning setup, performance analysis and visualized the featuresextracted by DenseNet20e1 from both datasets using t-SNE and to search for Hyperparameters of the classifires which can be accomplished by fatures combination in which features are extracted by CNNs, applying transfer learning, and the classifires.

Ningwei Wang, Hangzhe Liu [3], uses transfer learning and model integration and developed the detection of COVID-19. He researched the diagnostic and analytical capabilities of deep learning on chest radiographs and presented an image classification based on COVID-Net and classified chest X-ray images.

Antonious Makris [4], designed detecting COVID-19 from chest x-ray images using convolutional neural network and come up with the overall accuracy performance derived from pre-trained CNN models.

Luca Brunese, Francesco Mercaldo [5], develops pulmonary disease and COVID-19 detection from X- Rays and came to conclusion on 6,523 chest x-rays which belongs to different institutions which illustrates the effectiveness of the proposed approach.

Arpan Mangal, Surya Kalia [6], came up with COVID-19 detection using chest x-ray with an AUROC (Area under ROC Curve).

Linda Wang, Zhong Qiu Lin [7], Tailored deep convolutional neural network design for detection of COVID-19 cases from chest x-ray images. and evaluated the efficiency of the proposed covid-Net, both quantitative and qualitative analysis in order to acquire a deep understanding of its decision making behaviour and detection performance .

Shervin Minaee, Rahele Kafieh [8], predicted COVID-19 from Chest X-Ray images using deep learning and got up with the predicted probabilities with various modules.

Taban Majeed, Rasbar Rashid [9], develop CNN transfer learning to detect COVID-19 from chest X-rays and build their prediction using artifacts in images that have nothing to do with COVID-19 disease. Various architectures that were used in different scenarios, such as Normal vs. COVID-19 classification, Normal vs. COVID-19 vs. Viral (non-Covid) vs. Bacterial, Normal vs. COVID-19 vs. Viral vs. Bacterial

Ankita Shelke, Madhura Inamdar [10], automated covid-19 screening by using chest x-ray and deep learning and further classifies COVID-19 in three categories.

Khalid EI Asnaoui, Youness Chawki [11], automated detection of COVID-19 disease using x-ray images and deep learning in order to detect and classify coronavirus pneumonia using CT and x-ray images.

The drawback of Covid-19 diagnosis model over several study in this work was detecting COVID-19 using deep learning theory with the help of CNN network, were found to be observed with having high accuracy, sensitivity and precision metrics based on the epoch size. According to the existing work in this proposed system attains a class of high overall accuracy and precision which gives the outbreak of COVID-19 allows for an appropriate work balance and wider search range benefits diversity and inclusion. Communication and identification of coronavirus becomes easy to the individuals by considering and testing the chest x-ray images during this pandemic.

7. CONCLUSIONS

In this paper, The experiments are laid out keeping in mind the computer science perspective.,Inception V3 has better performance than VGG16 model in the field of binary classification. Whereas, for multiclass classification VGG16 is far better than InceptionV3. The studies and analysis also shows that for a small database augmentation is quite helpful. Augmentation has some disadvantages as well. Since augmentation of a large number of images from a small set of images effects model accuracy because noise is added while training the model. On the other hand, a very small number of images lead to the underfitting problems in the pre-trained model. Thus it will not produce the accurate results.

The encouraging results obtained using convolutional neural network models suggest that chest X-Ray can be useful for early detection of the covid-19 as compared to the time-consuming PCR test or expensive CT-Scan. Since we took less than 2000 images which is quite less, so it will be interesting to see the effect of large data and the use of other pre-trained models in future work. (appropriate data will directly enhance the model's accuracy ,since large data will lead to overfitting and small data will lead to underfitting thus affecting the accuracy)

REFERENCES

[1] Ali Narin, Ceren Kaya and Ziynet Pamuk "Automatic Detection of Coronavirus Disease (COVID-19) Using X-ray Images and Deep Convolutional Neural Networks" Zonguldak Bulent Ecevit University, 67100, Zonguldak, Turkey.

[2] Elene Firmeza Ohata, Gabriel Maia Bezerra, João Victor Souza das Chagas, Aloísio Vieira Lira Neto, Adriano Bessa Albuquerque, Victor Hugso Costa de Albuquerque, Senior Member, IEEE, and Pedro Pedrosa Rebouças Filho, Member, IEEE "Automatic Detection of COVID-19 Infection Using Chest X-Ray Images Through Transfer Learning".

[3] Ningwei Wang, Hongzhe Liu*, Cheng Xu Beijing Key Laboratory of Information Service Engineering Beijing Union University Beijing, 100101, China "Deep Learning for The Detection of COVID-19 Using Transfer Learning and Model Integration".

[4] Antonios Makris, Konstantinos Tserpes, and Loannis Kontopolus "COVID-19 Detection from Chest X-Ray images using Deep Learning and Convolutional Neural Networks"- Article · May 2020 DOI: 10.1101/2020.05.22.20110817.

[5] Luca Brunese , Francesco Mercaldoa, Alfonso Reginellic , Antonella Santone "Explainable Deep Learning for Pulmonary Disease and Coronavirus COVID-19 Detection from X- rays".
[6] Arpan Mangal, Surya Kalia , Harish Rajagopal , Krithika Rangarajan, Vinay Namboodiri, Subhashis Banerjee, and Chetan Arora "CovidAID: COVID-19 Detection Using Chest X-Ray"-Indian Institute of Technology Delhi.
[7] Linda Wang, Zhong Qiu Lin, and Alexander Wong "COVID-Net: A Tailored Deep Convolutional Neural Network Design for Detection of COVID
[8] Shervin Minaee, Rahela Kafifieh b, Milan Sonkac, Shakib Yazdanid, Ghazaleh Jamalipour Soufifie "Deep- COVID: Predicting COVID-19 from Chest X-Ray Images Using Deep Transfer Learning"- arXiv:2004.09363v3 [cs.CV]21 Jul 2020
[9] Taban Majeed , Rasber Rashid , Dashti Ali, and Aras Asaad "Problems of Deploying CNN Transfer Learning to Detect COVID-19 from Chest X- rays"- this version posted June 7, 2020
[10] Ankita Shelke Madhura Inamdar Vruddhi Shah Amanshu Tiwari Aafifiya Hussain Talha Chafekar Ninad Mehendale "Chest X-ray classifification using Deep learning for automated COVID-19 screening"- this version posted June 23, 2020.
[11] Khalid El Asnaoui & Youness Chawki, "Using X- ray images and deep learning for automated detection of coronavirus disease"- 22 May 2020.
[12] COVID-19 Images used in training are from, https://github.com/ieee8023/covid-chestxray-dataset